Pestic. Sci. 1996, **46**, 93–102

Communication to the Editor

Exposure of Four Filipino Farmers to Parathion-Methyl while Spraying String Beans*

Susan May F. Calumpang

National Crop Protection Center, University of the Philippines Los Baños College, Laguna, 4031 Philippines

(Received 15 May 1995; accepted 15 August 1995)

Abstract: Filipino farmers resist wearing protective garments while spraying, preferring to wear long-sleeved cotton polyester shirts and short or long trousers. The exposure of farmers while wearing this attire and spraying was assessed to determine what degree of protection it afforded farmers under tropical conditions. Absorbent pads were placed on the outer and inner wear on various body parts. Applicators sprayed parathion-methyl on fruiting string beans at the recommended rate and residues were analyzed by gas chromatography.

Each farmer had a characteristic spraying pattern which resulted in peculiar residue levels in some body parts. Inner exposure did not exceed the tolerable dermal exposure level during warm days while using proper spraying techniques. The use of long-sleeved cotton polyester shirt and thick polyester trousers provides, to a certain degree, protection for farmers during warm days. A change of clothing would be a more acceptable measure for farmers than wearing uncomfortable and impractical protective garments.

The following spraying techniques reduced farmer exposure: fully outstretched arm, minimal body twisting and smooth hand movements. The use of thick polyester long trousers, gloves or a suitable substitute and the removal of weeds within the crop area also reduce farmer exposure to insecticides. Re-designing the bottle to include a plastic lip, in order to avoid spillage, is also recommended to reduce exposure during the critical mixing stage. Laundering the shirt immediately after use removes a significant amount of residues (96–97%) and contributes towards the protection of farm workers.

These recommendations should provide useful data for incorporation in farmer-training programes on the proper use of pesticides.

Key words: exposure assessment, methyl parathion, string beans.

1 INTRODUCTION

Because of farmer exposure to pesticides during crop production, there is a need for the development of protective clothing suitable for the tropics. However, there has been resistance to the adoption of such clothing due to discomfort afforded by extremes of temperature and humidity. Farmers still prefer to wear long-sleeved cotton polyester shirts, short or long trousers and frequently spray barefoot.

The protection afforded by locally designed protective clothing during spray application of parathion-methyl by rice farmers using a knapsack sprayer has been assessed; plastic vests to cover the trunks, plastic

* Communicated as the result of a small unreplicated trial, with suggested methods for reducing risk to spray operators in the tropics.

Pestic. Sci. 0031-613X/96/$09.00

bags to cover the hands and plastic wrappings around the lower legs proved to be warm and were easily torn. Higher residue levels were found in farmers who wore no protective clothing. However, cholinesterase levels before and after exposure to parathion-methyl among farmers with and without protective clothing, did not differ significantly.[1]

In a similar study on rice farmers using monocrotophos in Calauan, Laguna, 'Gardman' protective clothing was used, which included a smock, an apron, nitrile rubber gloves and a fullface PVC visor. This was used only during mixing and biological monitoring for the urinary metabolite, dimethyl phosphate and blood cholinesterase levels showed that spraying for three consecutive days did not pose a health risk. The use of 'Gardman' protective clothing afforded no significant difference in whole blood and plasma cholinesterase levels, indicating that absorption occurred mainly during spraying activities when the protective clothing was not used.[2]

Field assessment of several protective clothing materials for the tropics has also been conducted using cotton, 'Tyvek' and 'Kleenguard' in cotton fields. Cotton garments were comfortable to wear in hot and humid condition, showed little sign of deterioration over the period of use and were as protective or more protective against methamidophos than the man-made materials.[3]

The exposure of farmers involved in rice, vegetable and mango production, using a food-quality dye to indicate contaminated areas and suits of lightweight protective material (polyethylene coated Tyvek), face masks and vinyl surgeons gloves, was assessed in the Philippines and Thailand. Estimation of exposure levels of the various body parts was made but penetration of the dye was not assessed.[4]

The importance of field surveys and assessment of exposure of operators to pesticides under actual application conditions is paramount. Such surveys provide essential data and are the only alternative to extrapolation from animal exposures.[5]

Up to 1993, parathion-methyl, a Category I poison,[6–8] was commonly used in the Philippines for string bean protection, along with methomyl, deltamethrin, endosulfan and monocrotophos.

To the best of our knowledge, there is no previous assessment of the exposure of Filipino farmers or of any Asian farmers to insecticides in string bean production while wearing protective attire.

This study was, therefore, conducted (1) to define the method, rate of application and environmental conditions under which parathion-methyl is applied, and (2) to collect data on the potential and actual exposure of farmers. In so doing, one can determine whether the actual exposure fell below or above the no-effect level of exposure and identify the body parts most exposed to contamination by parathion-methyl during string bean production.[9] More importantly, this study aimed (3) to make recommendations for proper spraying patterns and practices to reduce exposure of farm workers.

2 EXPERIMENTAL METHODS

2.1 Location

The trial was conducted in farmer-cooperators' vegetable farms in Barrio Bangyas, Calauan, Laguna, Philippines. Spraying activities were conducted on 2, 7, 9 and 11 December 1992.

2.2 Field experiment

Operators wore typical spraying attire consisting of long-sleeved cotton polyester shirts over a T-shirt and long trousers. Head covering was a cap and an inverted T-shirt wrapped over the head while covering the nose and mouth area. The shirt neckhole exposed the eyes and the feet and hands were bare.

Cellulose absorbent pads (46 cm^2) were placed on the outer and inner clothing over the following body parts: forehead, forearms, nose/mouth area, upper arms, sternum, scrotal area, back, thighs.[9] Applicators sprayed parathion-methyl, (as 'Folidol' M50 EC (Bayer Phils, Inc.)) on string beans during the fruiting stage at the rate of 0·5 kg AI. ha^{-1} using 600 litre ha^{-1} for a 900 m^2 experimental area. Farmers' hands were washed individually with 1 litre 80% ethanol.

All samples were kept frozen when not analyzed immediately.

2.3 Field recovery of parathion-methyl

Any losses of parathion-methyl due to storage, transit conditions and exposure to light were determined by placing 1 ml of spray formulation onto absorbent pads. Three pads each were used for exposed and unexposed treatment. Exposed pads were exposed to sunlight for a period of time equivalent to the duration of spray application in order to simulate field study conditions. These were stored in the same manner as the absorbent pads from field experiments.

2.4 Monitoring of weather conditions

For each farmer, temperature was monitored at the start and end of spraying activity, which lasted for about 2 h. Relative humidity and precipitation were also noted.

2.5 Effect of laundering

Cotton polyester shirt material (30 × 60 cm) was attached to bamboo sticks at both ends of the rectangle

and placed in the paddy at a height of 60 cm above the ground. Parathion-methyl spray solution was sprayed evenly over these pieces of cloth which were cut into half. Each half was cut into four equal squares (15 × 15 cm) and two opposite squares were analyzed as one sample. Unwashed sample was extracted directly, while the washed sample was rinsed with 500 ml tap water, washed with detergent solution (5%), rinsed three times with tap water and air-dried for 1 h. Laundering was done by hand. Parathion-methyl residues were extracted and analyzed by gas chromatography. This was conducted in triplicate.

2.6 Analytical methods

2.6.1 Extraction
Each absorbent pad was cut into squares (approx. 1 × 1 cm), placed inside a 500-ml Erlenmeyer flask and shaken in acetone (3 × 100 ml) for 30 min. The combined extracts were dried over anhydrous sodium sulfate (30 g) and rinsed with acetone (30 ml). The filtrate was concentrated under slight vacuum and taken up in methanol (5 ml) for analysis by gas chromatography.

Ethanol hand and feet washings (100 ml) were added to distilled water (150 ml) and extracted with dichloromethane (2 × 20 ml). The combined organic layers were dried over anhydrous sodium sulfate and concentrated under slight vacuum almost to dryness. The final extract was taken up in hexane for analysis by gas chromatography.

2.6.2 Gas-liquid chromatography
Parathion-methyl residues in the body pads were analyzed by gas-liquid chromatography using a Hewlett Packard 5840 gas chromatography equipped with an N-P flame ionization detector (N-P FID) using the following parameters:

Column: 91·4 cm, glass, 2 mm ID. 2% OV-101 on Chromosorb W-HP, 80/100

Temperature (°C):	Oven	160—165
	Injector	225
	Detector	300
Flow Rate (ml min^{-1}):	Nitrogen	30
	Hydrogen	3
	Compressed air	50

Quantitative estimation was based on peak area or peak height. To compensate for changes in detector sensitivity with time, an alternating injector sequence of one standard and five samples was used.

2.6.3 Calculations
Parathion-methyl residues per body part were calculated as follows:

$$\mu g \text{ per body part} = \frac{\mu g}{46 \text{ cm}^2} \times \text{area body part (cm}^2\text{)}$$

Body part values used were 80% of the values given by the US EPA Guidelines.[10,11] It was estimated that a reduction of this magnitude presented a more realistic estimate of body part areas for Filipinos.

Percentage permeation was calculated as follows:

$$\% \text{ permeation} = \frac{\text{Inner residues}}{\text{Outer residues}} \times 100$$

Outer residues on each body part were taken as the total amount that the body part received, inasmuch as the absorbent pad had a plastic lining which prevented residues in the pad from penetrating through the cotton material to which it was attached. Inner residues were those found in the absorbent pad placed under the outer shirt.

1. Specific exposure (head)
   (mg per person per kg AI)

$$= \frac{\text{Sum of nose and forehead (mg)}}{\text{kg AI handled}}$$

2. Specific exposure (body)
   (mg per person per kg AI)

$$= \frac{\text{Sum of all body parts (mg)}}{\text{kg AI handled}}$$

Outer and inner specific body exposure was calculated separately using the corresponding body patches.

Estimated exposure (EE) was calculated as follows:

$$\text{EE} = \frac{\sum \text{sum specific exposure} \times \text{area (ha)}}{\text{(nose and inner body) rate (kg AI ha}^{-1}\text{)}}$$

Residues in the nose area were included in the calculation for estimated exposure because this is an exposed head body part.

3 RESULTS AND DISCUSSION

3.1 Method verification

Recovery studies were run on control samples fortified with 5 μg of parathion-methyl per pad. Recovery values were 95·3 and 96·1%, giving an average recovery of 95·7%. The minimum detectable quantity (sensitivity) was 1 μg. Loss due to photodegradation during the conduct of the experiment was only 3%.

3.2 Exposure during mixing

Residues retained in the hands from the mixing process are shown in Table 1. The mixing process involved opening and closing the formulation bottle, measurement of the formulated material, transferring the formulated material to the spray tank, opening and closing the spray tank and shaking the spray tank to mix the spray solution thoroughly. Residues in the left hand are

TABLE 1
Parathion-methyl Residues on Farmers' Hands during Mixing Phase

	μg per hand			
	Farmer 1	*Farmer 2*	*Farmer 3*	*Farmer 4*
Left hand	2310	475400	23430	220600
Right hand	0·4	4640	143	25

consistently higher than in the right because all four farmers were right-handed and used the left hand to hold the formulation bottle.

Because of the high concentration of the active ingredient handled in this step, residue levels were mostly in the milligram per hand level. Extremely high levels were detected in both hands of Farmer 2, as spillage of the formulated material had occurred. It is, therefore, extremely important that some form of hand protection be used.

While there is farmer resistance to the use of gloves for reasons of economy and discomfort, it would be worthwhile to place each bottle inside a thick plastic bag so that direct contact with the bottle could be avoided. This would prevent farm workers from touching any formulated material that may have spilled and run down the bottle wall after use. A piece of plastic should also be used to cover both formulation bottle and sprayer tank.

3.3 Exposure during spraying

All four farmer-cooperators were of comparable height, right-handed and had several years of experience in spraying crops. Each farmer had a characteristic spraying pattern (Table 2) which resulted in significant residue levels in some particular body parts (Table 3 and 4).

Outer residues were consistently high in the thighs, legs and arms. Due to the height of the plants at fruiting stage (approx. 2 m), residues could also be detected in the head area which included the nose and forehead patches (Table 3).

3.3.1 Outer exposure

Farmer 1 sprayed both rows, on his left and right simultaneously, as in Fig. 1, resulting in very high outer residue levels found on the back and upper arm pads. Although his arm was fully outstretched, he twisted his

Fig. 1. Farmer 1: Sprays two rows simultaneously, with outstretched arm, lots of body twisting, smooth hand movement and wearing thick polyester pants on a cool day.

TABLE 2
Spraying Pattern of Some Farmer-Cooperators in String Bean Production

	Farmer 1	*Farmer 2*	*Farmer 3*	*Farmer 4*
(1)	Sprays two rows simultaneously	Sprays two rows simultaneously	Sprays two rows simultaneously	Sprays one row at a time
(2)	Arm outstretched	Arm outstretched	Arm not outstretched	Arm outstretched
(3)	Lots of body twisting	Minimal body twisting	Minimal body twisting	Minimal body twisting
(4)	Smooth hand movement	Smooth hand movement	Slight pause in downward motion	Smooth hand movement
(5)	Thick polyester (jogging trousers)	Thick polyester (jogging trousers)	Thick polyester (jogging trousers)	Thin polyester trousers

TABLE 3
Parathion-methyl Residues on Various Body Parts of Farmer while Spraying String Beans at Fruiting Stage: Outer Exposure

Body part	*μg per body part*			
	Farmer 1	*Farmer 2*	*Farmer 3*	*Farmer 4*
Thigh, left	15370	6795	6274	23000
Thigh, right	15420	13590	72730	9742
Leg, left	8383	3397	16690	782
Leg, right	10060	767	13620	880
Upper-arm, left	29220	1402	6098	4210
Upper-arm, right	29580	1591	6199	2935
Back, left	19860	349	947	335
Back, right	4530	661	939	428
Shoulder, left	83	17	64	113
Shoulder, right	65	27	176	103
Forearm, left	943	520	5011	1288
Forearm, right	447	525	7293	1250
Sternum	1561	446	19490	5515
Scrotal area	60	33	360	211
Head	1021	151	5269	275

body to the side where the spray lance was located so that high residue levels were detected on the pads attached to his chest and upper arms. Residues on the back pad were exceptionally high due to frequent contact with newly sprayed foliage and not due to leakage from the sprayer. Although the hand swing of Farmer 1 went from left to right, residue levels on the pad covering the scrotal area were not as high as those found on Farmer 3 because the former had his hand fully outstretched.

Farmer 2 also had low outer residue levels on the pad in the scrotal area even if he sprayed from left to right. Residue levels on the head because of his fully outstretched right arm were even lower than for Farmer 1 because of minimal body twisting (Fig. 2).

Like Farmer 2, Farmer 3 also sprayed from left to right with minimal body twisting but his right arm was bent as in Fig. 3. This led to extremely high residue levels on the chest and head pads (19·5 mg and 5·3 mg, respectively). The head pad residues for Farmer 3 were 5, 19 and 35 times greater than for Farmers 1, 4 and 2, respectively; chest pad residue levels were 3·5, 12 and 44 times greater than for Farmers 4, 1 and 2, respectively. Residues in the scrotal area pad were 1·7, 6 and 11 times greater on Farmer 3 than on Farmers 4, 1 and 2, respectively.

TABLE 4
Parathion-methyl Residues on Various Body Parts of Farmer while Spraying String Beans at Fruiting Stage: Inner Exposure

Body part	*μg per body part*			
	Farmer 1	*Farmer 2*	*Farmer 3*	*Farmer 4*
Thigh, left	1750	118	382	1136
Thigh, right	2132	129	1273	1514
Leg, left	4592	89	285	287
Leg, right	2838	220	202	793
Upper-arm, left	250	84	149	631
Upper-arm, right	912	27	30	210
Back, left	248	29	30	254
Back, right	29	8	148	145
Shoulder, left	0·5	2	15	82
Shoulder, right	1	2	12	28
Forearm, left	207	22	143	650
Forearm, right	428	128	269	162
Sternum	664	115	261	409

Fig. 2. Farmer 2: Sprays two rows simultaneously, with outstretched arm, minimal body twisting, smooth hand movement and wearing thick polyester pants on a warm day.

Therefore, it is evident that a fully stretched arm helps reduce exposure, especially since most Filipino farmers walk into the spray mist while spraying.

The spraying technique of Farmer 3 also produced extremely high outer residues in the thigh and leg pads, notably on the right thigh pad. When the spray lance was swung from left to right there was a slight pause in the downward motion, so that the spray lance stayed down slightly longer than with the other farmers. This small difference gave rise to very high outer residue levels on the thigh and leg pads which were up to 4 and 18 times higher than for the other farmer-cooperators.

Fig. 3. Farmer 3: Sprays two rows simultaneously, with minimal stretching of arm and body twisting, slight pause in downward hand motion and wearing thick polyester pants on a warm day.

Farmer 4 sprayed only one side of each string bean row, with outstretched arms and minimal body twisting (Fig. 4). This spraying pattern gave rise to low outer residue levels in the legs, back, forearms, scrotal and head areas.

Of the four spraying patterns, that of Farmer 2 gave lowest outer residue levels of parathion-methyl in most body parts. A total of 30·2 mg parathion-methyl was detected on Farmer 2 while the highest level (137·6 mg) was detected on Farmer 1.

3.3.2 Inner exposure

Parathion-methyl residues that penetrated through the cotton T-shirt and long trousers onto the pads attached to either the skin or inner wear are shown in Table 4, while percentage penetration values are shown in Table 5. Only 0·98 mg of parathion-methyl penetrated through the outer clothing of Farmer 2, while the highest amount (14 mg) penetrated through the outer clothing of Farmer 1.

Residue levels were still consistently high on the thigh, leg and arm pads (Table 4). Although inner parathion-methyl residue levels on the thigh pads ranged from 118 to 2131 μg per thigh pad, this represented a penetration of only 1–15% of the outer residues. Inner residues on the leg pads also ranged from 88·8 to 4592 μg per leg pad, representing 1·5–90% penetration.

The degree of penetration onto the pads covering the legs and thighs is largely affected by the trouser material used (Table 5). Farmers 1, 2 and 3 used thick polyester jogging trousers while Farmer 4 used pants of thin polyester material. Thus, Farmers 2 and 3 had extremely low percentage penetration values, mostly less than 10% except for the right leg of Farmer 2 with 29% penetration. Farmer 4, who wore thin polyester trousers, had higher percentage penetration values, ranging from 5 to 90% on the leg and thigh areas.

While outer residue levels on the pads covering the upper arms were extremely high, ranging from 1401 to 29 582 μg per upper arm, penetration of these residues was only 0·5–15%. This indicates that, for body parts which are not pressure points, like the upper arms, back and chest, penetration of residues through the cotton polyester shirt material can be minimal, except in extreme cases of sprayer leaks.

Percentage penetration in the inner shoulder pads was quite low for Farmers 1, 2 and 3. All three farmers had less than 15% penetration except for the left shoulder of Farmer 3 which had 24% penetration. In general, the left shoulder had a greater percentage penetration

TABLE 5
Percentage Penetration of Parathion-methyl residues into Farmer Clothing while Spraying String Beans at Fruiting stage

Body part	*Farmer 1*	*Farmer 2*	*Farmer 3*	*Farmer 4*
Thigh, left	11·4	1·7	6·1	4·9
Thigh, right	13·0	1·0	1·6	15·5
Leg, left	54·8	2·6	1·7	36·6
Leg, right	28·2	28·6	1·5	90·2
Upper-arm, left	0·8	6·0	2·4	15·0
Upper-arm, right	3·1	1·7	0·5	7·2
Back, left	1·2	8·4	3·2	75·8
Back, right	0·6	1·2	15·7	34·0
Shoulder, left	0·6	13·7	24·0	72·7
Shoulder, right	1·5	6·4	7·1	27·5
Forearm, left	21·9	4·3	2·8	50·5
Forearm,right	95·6	24·4	3·7	12·9
Sternum	42·6	25·8	1·3	7·4

than the right. The left shoulder is a pressure point, as the left hand is used to pump the spray tank. Thus, it is to be expected that residues would penetrate onto this body part easily.

Farmer 4 showed greater percentage penetration on both shoulders (27 and 73%) than the other farmers. This difference may be attributed to the cumulative effect of the repeated up and down hand movement of both arms and the different temperature; ambient temperature on Farmer 4's spraying date ranged from 28 to 31°C while Farmer 2 and 3 sprayed on warmer days, 29–38°C (Table 6).

3.4 Specific dermal exposure

Specific exposure of each farmer is shown in Table 6. This has been separately categorized as inner and outer exposure for the body, as the body was covered and as such, residues which penetrated the long-sleeved cotton

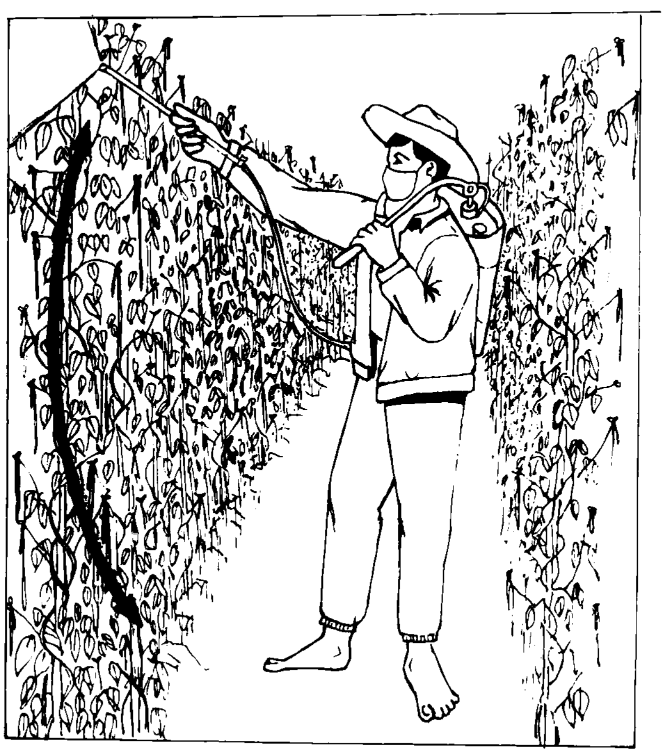

Fig. 4. Farmer 4: Sprays one row at a time, with outstretched arm, minimal body twisting, smooth hand movement and wearing thin polyester pants on a cool day.

TABLE 6
Specific Dermal Exposure of Farmers to parathion-methyl while Spraying String Beans at Fruiting Stage (mg per person per kg AI. handled)

Farmer No.	Outer exposure		Inner exposure	Reduction (%)	Temperature range (°C)	Relative humidity (%)
	Head	Body	Head + Body			
1	22·7	3035	312·6	90	28–31	89
2	3·3	664	23·8	96	29–38	90
3	117·1	3484	70·2	98	34–38	81
4	57·9	1128	140·2	88	28–31	85

polyester shirt and long trousers were the only ones considered available for dermal adsorption.

Values shown account for only 80% of the calculated values using the body areas given in the US-EPA guidelines.[9] It is estimated that a Filipino farmer would have a body area that is about 20% less than his counterpart in the western world.

Outer and inner specific exposure values for the body show the significant reduction of residues. A reduction of as much as 96–98% of the residues present on the outerwear is achieved on the innerwear through the use of a cotton polyester shirt and thick polyester long trousers. Such a reduction means significant protection for the farmer, as only inner residues are available for dermal adsorption.

Specific exposure of the head region ranged from 3·3 to 117 mg parathion-methyl per person per kg AI. handled. These values show a wide range of variability and most are within the range of values documented for hand-held equipment in high crops.[11]

Only the highest value (117 mg per person per kg AI.) exceeds the range documented for parathion, a very similar but more toxic compound than parathion-methyl. Only 12·2 mg per person per kg AI. has so far been documented for exposure using a knapsack sprayer with a single lance for high crops (fruits).[11]

Specific exposure of the inner body was also compared to the data base which documented only outer body exposure and all four values generated were within the documented range. It should be noted, however, that such documentation involved outer dermal exposure using spraying patterns and crops totally different from those assessed in this study. This emphasizes the great need to generate local data to assess various use patterns in crops where pesticide use is extensive or where exposure is high.

3.5 Estimated dermal exposure

Estimated exposure values were calculated for 1000 m^2 and 2500 m^2 (Table 7). Calculation used the entire inner body specific exposure and the specific exposure of 500 cm^2 of the head area using values from the nose patch alone. The entire head has a surface area of 1300 cm^2 but the farmer cooperator used a cap and a kerchief or an inverted T-shirt. We estimated an exposed area of only 500 cm^2 and residues did not penetrate the cap.

The tolerable dermal exposure of parathion-methyl was calculated as:

$$D_{\text{tol}} = \frac{\text{NOEL}_\text{D} \times 50\ \text{kg BW}}{25\ (\text{SF})} = \frac{10\ \text{mg kg}^{-1} \times 50\ \text{kg BW}}{25}$$

giving a final D_{tol} value of 20 mg, using NOEL (dermal) from subacute dermal toxicity studies. Exposure for the farmer-cooperators was estimated for 1000 m^2 and 2500 m^2 d^{-1}, areas which small farmer owners and contractual workers, respectively, usually cover in a day.

If only 1000 m^2 is sprayed per day, all four spraying patterns would give exposures which are below the dermal tolerable exposure for parathion-methyl. Spraying 2500 m^2 during warm days (29–38°C) would also give exposures which are below the dermal tolerable exposure. The latter was only exceeded when spraying was done during cool days using the spraying pattern of Farmer 1 which involved a lot of body twisting.

Farm workers may therefore spray as much as 2500 m^2 of high crops on warm days and should change their shirts every 1000 m^2 on cool days to avoid exceeding the dermal tolerable exposure of 20 mg for parathion-methyl. Frequent changes of clothing would be better than wearing uncomfortable and impractical protective garments. This minimum crop area could be increased when a less toxic insecticide was sprayed.

TABLE 7
Estimated Exposure for a Farmer Spraying Parathion-methyl on Fruiting String Beans Covering Different Areas (mg per person per day)

Farmer	1000 m^2	2500 m^2
1	15·6	39·1
2	1·2	3·0
3	3·5	8·8
4	7·0	17·5

TABLE 8
Effect of Laundering on Parathion-methyl Residues in Cotton Material

Replicate	*Residues* Unwashed (μg)	Washed (μg)	*Reduction* (%)
1	3602	147	96
2	4252	120	97
3	3648	84	98
Average	3834 ($\pm$362)	117 ($\pm$32)	97 ($\pm$0·9)

3.6 Effect of weather and weed cover

The effect of temperature on the penetration of residues can be seen in the values for Farmer 4 who sprayed on a cool day with a temperature range of 28–31°C (Table 6). In general, percentage penetration in the body parts of Farmer 4 were higher than for Farmers 1, 2 and 3, except in cases where these were almost equal to values for Farmer 1, who also sprayed on a cool day. Farmer 4 showed four body parts with more than 50% penetration, namely: right leg, left back, left shoulder and left forearm. Farmer 1 had only two body parts which exceeded 50% penetration: left leg and right forearm, while Farmers 2 and 3 did not have any.

Although the outer body exposure was extremely high, the inner body exposure showed a great reduction of residues. On cool days (28–31°C), an 88–90% reduction in residues was obtained by the use of a long-sleeved cotton polyester shirt and long pants, while on warm days (29–38°C) as much as 98% reduction could be attained.

These findings show the profound effect of ambient temperature on exposure, where evaporation of water from the cotton polyester shirt reduces the rate of penetration of the residues and consequently reduces exposure of farm workers.

Farmers 1, 2 and 3 wore thick polyester jogging trousers but only Farmer 1 had a high percentage penetration. Farmer 1's case is slightly different from those of Farmers 2 and 3 in that he sprayed during a very cloudy day where there was a very slight drizzle for a few minutes. This was enough to wet the weed cover surrounding the crop stand which also wet the farmer's legs. The presence of precipitation contributed greatly to increased penetration of parathion-methyl residues. Percentage penetration in the legs ranged from 28 to 55% for Farmer 1 alone and from 1 to 29% for Farmers 2 and 3 (Table 5).

Evidently, weed cover within the crop should be reduced because it serves as an alternative host or habitat for insect pests besides contributing to increased exposure of farm workers involved in spraying activities.

3.7 Effect of laundering

The removal of parathion-methyl residues from various types of fabrics using mechanical washing has been well studied.[12–15] Laundering removes pesticide residues present in the cloth material and available for skin contamination. When done immediately after the spraying exercise, laundering can remove as much as 96–97% of the parathion-methyl residues initially present (Table 8).

4 CONCLUSIONS AND RECOMMENDATIONS

The use of a long-sleeved cotton polyester shirt and thick polyester trousers provides protection for some farm workers to dermal exposure while spraying string beans. The reduction of inner residues is higher during warm days.

These results show that the actual inner exposure of applicators to parathion-methyl are below the tolerable dermal exposure while using the long-sleeved cotton polyester shirt and thick long trousers. Extrapolation to a daily area of 2500 m^2 suggested that, for most applicators, the actual exposure would not exceed the tolerable dermal exposure.

The use of short trousers during spraying activities is not acceptable. The highest residue levels are found on the thigh and leg pads. The use of long trousers of thick polyester material, such as that used in jogging trousers, is highly recommended.

Spraying activities conducted on a warm day minimize operator exposure. An acceptable protection measure for farmers on warm days would be a change of attire after spraying parathion-methyl over an area of about 2500 m^2 for high crops.

Spraying technique, as in the direction of the hand swing and the degree with which the arm is out stretched, affects the amount of residues in the various body parts. Body twisting has to be kept to a minimum and smooth hand movements are highly recommended to avoid residue levels being concentrated in a particular body part. It cannot be over-emphasized that stretching of the arm holding the spray lance will reduce exposure.

Gloves must be used and formulation bottles placed inside a thick plastic bag to avoid direct hand contact with the bottle. A piece of plastic should also be used to cover both formulation bottle and sprayer tank.

The design of bottles should be improved; a plastic lip around the mouth of the bottle, as used in bottles for acids, would significantly reduce hand exposure to spilled formulated material during the mixing phase.

The usual practice of hanging a used shirt to dry and reusing it for another day's spraying activity should definitely be avoided. A clean, hand-laundered shirt should be used on each day of spraying.

These results provide useful data for incorporation in farmer training programmes on the proper use of pesticides and, it is hoped, may persuade farmers to follow the recommendations.

While this study is limited by the number of farmers assessed, results do indicate methods of reducing operator risk. Additional data are currently being generated to substantiate these findings.

The exposure of farmers to other insecticides used in string bean production, and on other crops such as mangoes, cabbage and other crucifers needs to be examined. Such information will determine whether farmers are exposed to excessive levels of insecticides while spraying.

5 ACKNOWLEDGEMENT

The author wishes to acknowledge the financial assistance of the Department of Agriculture, Republic of the Philippines—National Agricultural and Fishery Council (DA-NAFC) and the assistance of Bayer AG, Monheim, Germany and Bayer Philippines, Inc. The assistance of R. Allado is also acknowledged.

REFERENCES

1. Cortes-Maramba, N. P., *Final Report—Assessment of adequacy of protection of pesticide handlers.* Fertilizer and Pesticide Authority, Department of Agriculture, Philippines, 1988.
2. Castaneda, C. P., Dumas, E. P. & Van Sittert, N. J., Field study of exposure and health effects following knapsack application of an Azodrin formulation to rice in the Philippines. The Shell Chemical Co. (Philippines) Inc., 1989.
3. GIFAP, *Field evaluation of protective clothing materials in a tropical climate. Thailand*—September 1988. Brussels, Belgium, 1988, 36 pp.
4. Ambridge, E. M. & Haines, I. H., Some aspects of pesticides used and human safety in Southeast Asia. In *Proc. 11th Internat. Congr. Plant Prot.* 5-9 October 1987, Manila, Philippines, Vol. 1, pp. 219–24.
5. Copplestone, J. F., Methods for field assessment of exposure to pesticides. In *Field Worker Exposure During Pesticide Application.* ed. W. F. Tordoir & E. A. H. van Heemstra. Studies in Environmental Science 7. Elsevier Scientific Publishing Co. New York, 1980, pp 17–19.
6. Calumpang, S. M. F., Tejada, A. W. & Hoque, M. M., Insecticide residues in market basket samples: string beans (1987). *NCPC Newsletter.* **II** (1988) 7. National Crop Protection Center, University of the Philippines, Los Banos.
7. Tejada, A. W., Calumpang, S. M. F., Barredo, M. J. V. & Magallona, E. D., Insecticide residues in field sprayed string beans (*Vigna sesquipedalis* Fruw.) I. Monocrotophos, fenvalerate, cypermethrin, BPMC and chlorpyrifos. *Phil. Agric.*, **72** (1989) 391–400.
8. Tejada, A. W., Pesticide management survey in vegetable producing areas in Laguna. National Crop Protection Center, University of the Philippines Los Banos Annual Report. 1993.
9. WHO, Survey of exposure to organophosphorus pesticides in agriculture—standard protocol. VBC/75·9. Geneva, Switzerland.
10. US Environmental Protection Agency Pesticide Assessment Guideline, Subdivision U: Applicators Exposure Monitoring, 1987.
11. Lundehn, J. R., Westphal, D., Kieczka, H., Krebs, B., Locher-Bolz, S., Maasfeld, W. & Peck, E. D., *Uniform Principles for Safeguarding the Health of Applicators of Plant Protection Products (Uniform Principles for Operator Protection).* Kommissionsverlag Paul Parey, Berlin und Hamburg, Seubuschring 9–17 D 1000 Berlin **42**, 1992, pp. 61–112.
12. Easley, C. B., Laughlin, J. M., Gold, R. E. & Schmidt, K., Detergent and water temperature as factors in parathion-methyl removal from denim fabrics. *Bull. Environ. Contam. Toxicol.*, **28** (1982) 239–44.
13. Hild, D. N., Laughlin, J. M. & Gold, R. E., Laundry parameters as factors in lowering parathion-methyl residues in cotton/polyester fabrics. *Arch. Environ. Contam. Toxicol.*, **18** (1989) 908–14.
14. Laughlin, J. & Gold, R. E., Thermal and chemical energy in laundering to maximize parathion-methyl removal for cotton/polyester fabrics. *Arch. Environ. Contam. Toxicol.*, **20** (1991) 49–55.
15. Laughlin, J. & Gold, R. E., Parathion-methyl residue removal on protective apparel fabric soiled with synthetic sebum or vegetable oil. *Arch. Environ. Contam. Toxicol.*, **19** (1990) 205–13.